THE MIGRATION OF ILLINOIS FISHES

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The Migration of Illinois Fishes

by

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About 7,000 Illinois fishes of the larger and more important kinds have been marked with serially numbered tags and released in the principal streams and lakes of the state. At present we have sufficiently detailed information on the time and place of recapture of more than 120 of these tagged fishes to warrant a preliminary report. Beginning in 1929, Illinois has suffered four years of extreme drouth. During these years unusually low stages of water have prevailed in all of our streams. Since most of these fishes bore tags during this period, the results which we have obtained may reflect in some degree the effects of drouth on fish movements.

It has been found that the movements of fishes as determined by tagging are random in nature, at least in their general aspects and over considerable periods of time. This randomness of their movements is shown by the fact that they are retaken at distances from the starting point proportional to the square root of the time. This relationship of time and distance may be utilized to estimate average distances from the starting point. These calculated average distances are shown in Table I, p. 2 for periods of one day, one week, one month, one year, and five years. This table shows rather accurately the rate at which waters depleted of their fishes, but connected with waters containing desirable kinds, may be restocked by the natural movements of the fishes themselves. It also indicates to what degree we may expect fishes to utilize uniformly the food resources in the different portions of a stream or lake.

These returns from tagged fishes have given information on other questions. Crappies, sunfishes, and basses move upstream strikingly faster than downstream, while, on the other hand, the carp moves downstream rather than upstream. The black bullhead makes rapid upstream migrations in spring and tends to run in schools, since on one occasion an angler caught in one day three tagged bullheads, which had been tagged 15 miles downstream 18 days earlier. A number of instances have given measurements of growth in length and weight over considerable periods of time and enables a check on the rates of growth obtained by counting the annual rings in scales. Striking differences in the capacities of different fishes to carry tags have appeared, certain kinds not carrying tags more than a few days or weeks, while others seemingly carry tags indefinitely.

Table I.—Calculated average migrations in miles over various periods of time

Kind of Fish	One Day	One Week	One Month	One Year	Five Years
White bass	1.25	3.3	6.8	23.9	53.4
Rock bass	0.79	2.1	4.3	15.1	33.7
Black crappie	1.31	3.5	7.2	25.0	56.0
White crappie	1.19	3.1	6.5	22.7	50.9
Bluegill	0.75	2.0	4.1	14.3	32.0
*Green sunfish	0.04	0.1	0.2	0.8	1.8
Yellow perch	0.14	0.4	0.8	2.7	6.0
Pickerel	0.12	0.3	0.7	2.3	5.2
*Sheepshead	2.06+	5.4+	11.3+	39.3+	87.9+
Black bullhead	1.26	3.3	6.9	24.1	53.8
Flathead cat	0.81	2.1	4.4	15.5	34.6
*Channel cat	0.08	0.2	0.4	1.6	3.5
*Common redhorse	0.10	0.3	0.5	1.9	4.3
Black sucker	0.28	0.7	1.5	5.3	11.9
Quillback	0.50	1.3	2.7	9.5	21.3
Small mouth buffalo	1.07	2.8	5.9	20.4	45.7
Red mouth buffalo	1.73	4.6	9.5	33.1	73.9
Carp	0.42	1.1	2.3	8.0	17.9

*The reliability of the figures given for these fishes is questionable.

Early in 1926 we started tagging fishes with a hundred aluminum tags furnished by the U. S. Bureau of Fisheries. No further tagging was done until the summer of 1929 when we changed to tags made of non-corrosive metal in two sizes—the so-called No. 2's and No. 3's. These tags bore a serial number on one side and the letters INHS, for Illinois Natural History Survey, on the other. In the course of four seasons of field work, 1929-1932, 7,000 fishes have been tagged as a part of aquatic surveys and fisheries research covering the more important waters of the state. The fishes were usually tagged and released near the spot where they were caught, although occasionally they were released a few miles away. The localities in Illinois where fishes were tagged are indicated in Fig. 1., p. 4.

In order to secure returns from these tagged fishes placards showing an illustration of a fish with a tag attached and worded as follows were posted at places where fishing licenses are sold, boat yards, sportsmen's hotels, fish market boats, resorts, etc.:

WATCH FOR TAGGED FISH

The migration and growth of important kinds of Illinois fishes are being studied by marking them with small metal tags clamped to the upper side of the tail fin. These tags have a number on one side and INHS on the other.

Bass, crappies, blue gills, sunfish, wall-eyed pike, pickerel, sheepshead, channel cat, mud cat, bullheads, carp, buffalo, redhorse, suckers, etc., have been tagged in many parts of Illinois. Records have been kept showing the exact kind, weight, length, tag number, and the place and date that each fish was tagged and released.

We invite fishermen to cooperate by returning the tags and about 10 scales from the middle of the left side of the fish to the

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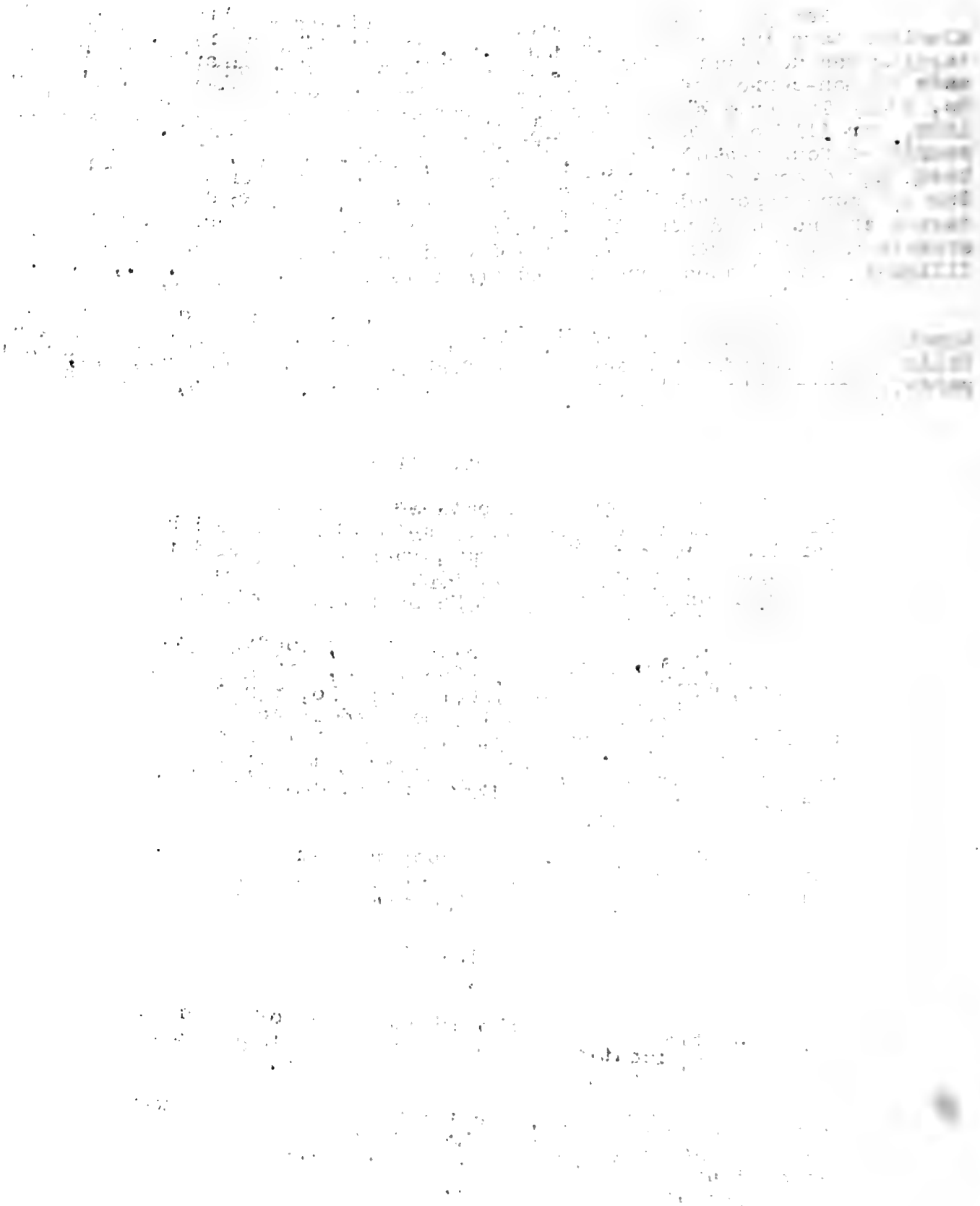
with information showing the body of water and exact location where the fish was taken, and if possible, the weight and length.

If desired, the tag will be returned with information showing how far the fish had travelled and how much it had grown since it was originally tagged.



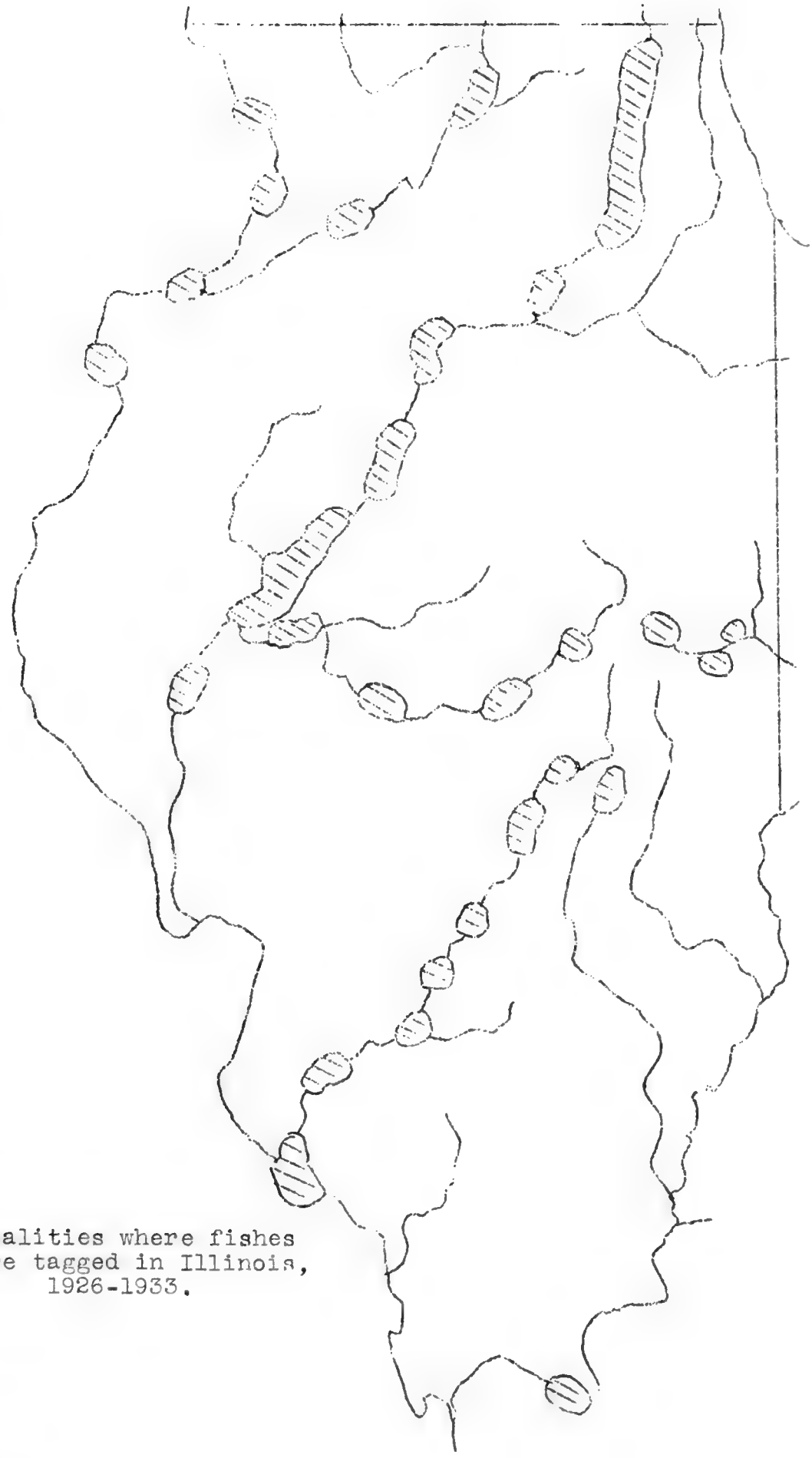


Fig. 1.—Localities where fishes were tagged in Illinois, 1926-1933.

From time to time information given to newspapers told of these experiments and requested the cooperation of hook-and-line and commercial fishermen.

The numbers of fishes tagged are summarized by kinds and streams in Table II, p. 6. The number of returns of tags from the different kinds are summarized in Table III, p. 7. Hook-and-line fishermen returned 45 tags, commercial fishermen 31 tags, while 47 tagged fishes were recaptured in our own nets after one, two, or at most a few days. The maximum and average periods that tags were borne by the different kinds are also given in Table III. Tabulated details of the history of each tagged fish whose capture was reported are given in Table IV, pp. 8-16.

Grateful acknowledgments are due those anglers and commercial fishermen who furnished the data on which this report is based. In all parts of the state the field work has been greatly facilitated by commercial fishermen who have given freely of their intimate knowledge of Illinois waters, fish life, and fishing methods. I wish to thank the people who have made up the field parties of the Natural History Survey during these different seasons of field work and especially Mr. Francis D. Hunt, who has been in immediate charge of these parties.

Soon after the reports on the place and date of capture of tagged fishes began to accumulate, it was obvious that the shortest water distance from the place the fishes were released to the place where they were retaken was not proportional to the length of time they were free. The longer the time the smaller was the average daily distance traveled.

By watching the movements of fishes in clear waters it appears that there is at least some degree of randomness. In casting about for some method of measuring this degree of randomness, it was found convenient to compare the movements of fishes with the movements of Brownian particles in a liquid, since the latter seem to typify a movement entirely random in nature. The rate of movement of Brownian particles has been expressed in a series of equations by Professor Albert Einstein. Briefly, these equations state that the distance of a Brownian particle from the starting point is, on the average, proportional to the square root of the time. By applying this measure of randomness of movement to fishes it may readily be ascertained whether or not fishes exhibit a sort of "homing instinct," or whether they tend to swim in certain directions.

For each fish, the shortest water distance in miles has been divided by the square root of the number of days the tag was carried. This gives an expression of the number of miles, or fraction of a mile, that this fish may be expected to be distant after one day. Such numbers for different fishes are weighted by the number of days the tags were carried and averaged in various ways to give what may be called migration constants. These migration constants may be defined as the calculated average distance in miles away from the starting point after one day of time.

Table II.—Numbers of fishes tagged in Illinois waters to July 1, 1933

Kind of fish	Mississippi River (Savanna to New Boston)	Illinois River & bottomland lakes	Rock River	Kaskaskia River	Sangamon River	Fox River & Fox Lakes	Lakes along Ohio River	Totals
Large mouth black bass	8	161	2		8	51	3	233
Small mouth black bass			12			12		24
Rock bass				17		59		76
Warmouth bass		4				32		36
White bass			1			32	2	35
Yellow bass	6	14				1		21
Black crappie	12	530	7	9	37	224	10	829
White crappie	68	416	52	40	41	152	157	926
Bluegill	2	112	2	1	6	260	21	404
Pumpkinseed				13		16		29
Long-eared sunfish				10				10
Green sunfish		1		1	3			5
Garman's sunfish		1						1
Wall-eyed pike		3	45			2		50
Yellow perch		17				8		25
Pickerel						60		60
Grass pike						1		1
Sheepshead	40	67	77	4	26			214
Eel				4			2	6
Channel cat	71	99	22	74	140	116	2	524
Blue cat				1				1
Flathead cat	13		3	41	30		1	88
Black bullhead	4	45		289	292	89		719
Speckled bullhead		15				101		116
Yellow bullhead		12		1	9	11		33
Carp	88	1228	72	48	113	134	10	1693
Red mouth buffalo		164	8	1	2		2	177
Mongrel buffalo		23	2	1	1		1	28
Small mouth buffalo	1	28		5			15	49
Quillback		34	3	5		5		47
Sweet sucker		1				3		4
Black sucker		9			2	23		34
Hog sucker			1			7		8
White-nosed sucker		1				46		47
Common red horse			7	2	1	90		100
Short-headed redhorse		1	1	12	1	57		72
Spoonbill cat							90	90
Totals	313	2986	317	579	712	1592	316	6815
Fishes tagged in state fish hatcheries and miscellaneous other waters (large mouth black bass, channel cat, black crappies, white crappies, and bluegills								323
Grand total -								7138

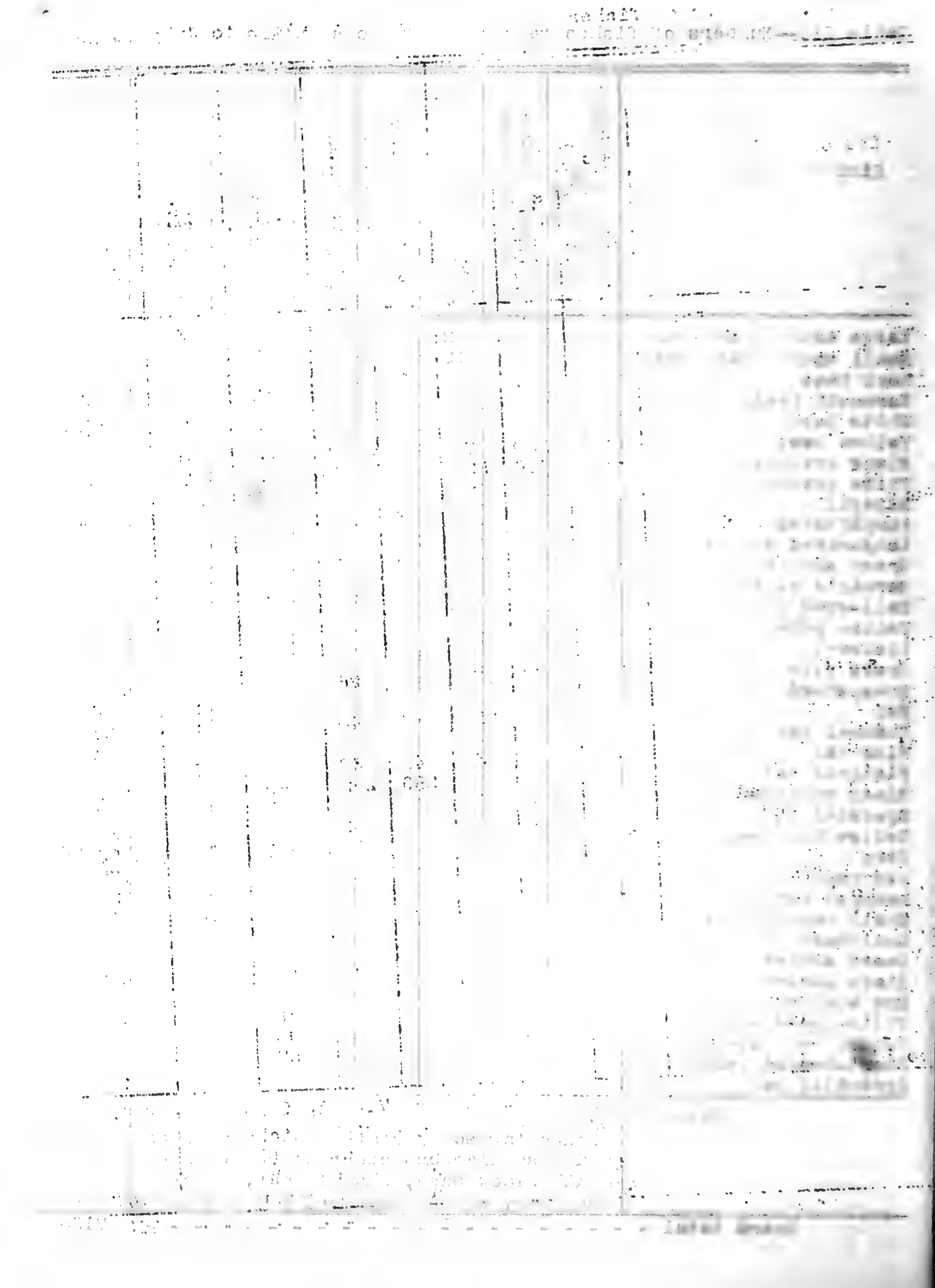


Table III.—Summary of tags returned

Kind of fish	Number tagged	Number of tags returned			No. of days tags were carried (excluding those retaken by INHS)	
		Hook and line fishermen	Commercial fishermen	INHS field parties	Maximum	Average
Large mouth bass	233	1(?)*			about 650	
Small mouth bass	24					
Rock bass	76	2		1	6	4
Warmouth bass	36					
White bass	35	1			23	---
Yellow bass	21					
Black crappie	829	8	2	5	251	111
White crappie	926	4	3	10	117	51
Bluegill	404	2			108	56
Pumpkinseed	29			1		
Long-eared sunfish	10					
Green sunfish	5			1		
Garman's sunfish	1					
Wall-eyed pike	50			1		
Yellow perch	25	1			115	---
Pickerel	60	4		1	1174	686
Grass pike	1					
Sheepshead	214	1		1	(?)**	---
Eel	6					
Channel cat	524	2			620	326
Blue cat	1					
Flathead cat	88	5			1067	500
Black bullhead	719	5		10	277	79
Speckled bullhead	116			2		
Yellow bullhead	33					
Carp	1693	8	20	9	990	231
Red mouth buffalo	177		4	1	170	108
Mongrel buffalo	28					
Small mouth buffalo	49		1		8	---
Quillback	47		1	1	24	---
Sweet sucker	4					
Black sucker	34	2			159	159
Hog sucker	8					
White-nosed sucker	47					
Common red horse	100			1		
Short-headed red horse	72					
Spoonbill cat	90			2		
Totals	6815	46	31	47		

* A tagged fish, reported to be a 4-pound black bass, was taken at Elgin about May 10, 1932. The tag number was read incorrectly and the fish returned to the water.

**On Feb. 16, 1933 officers of the Iowa State Fish and Game Commission kindly forwarded a tag given them by an itinerant fisherman with the information that it was taken near Rockingham Light on the Mississippi River about Aug. 16, 1932. This date is obviously incorrect since this fish was not tagged until Aug. 29, 1932. We have not been able to find the fisherman, Earl Thompson.

Table IV.—Migration of Illinois fishes

BLACK CRAPPIE

Tag Number	Stream	Location	Date	Wgt., Lbs.	Water Distance Miles	Migration	No. Days Tagged	Caught, or Reported by
INHS 2798	Fox River	3 miles above Grass Lake	July 12, 1930	0.4	9.	downstream	222	W.R.Hamburger
INHS 3570	" "	Mouth of Indian Cr.	Sept. 8, 1930	0.6	2.	downstream	29	L.E.Armstrong
INHS 4963	Illinois R.	Meredosia Bay	July 21, 1931	0.55	0.5	in lake	2	I. N. H. S.
INHS 4964	" "	" "	July 21, 1931	0.55	0.5	in lake	1.3	" " " "
INHS 4986	" "	" "	July 21, 1931	0.7	0.5	in lake	0.4	" " " "
INHS 5454	" "	" "	July 31, 1931	0.5	0.06	in lake	0.4	" " " "
INHS 5458	" "	" "	July 31, 1931	0.5	3.3	in lake	13	" " " "
INHS 5761	" "	Big Lake Pumping Station	Nov. 4, 1931	0.3	12.	upstream	118	Tom Ganer
INHS 5979	" "	" "	Nov. 6, 1931	0.55	12.	upstream	11	Oscar Kinney
INHS 6259	" "	" "	Nov. 6, 1931	0.2	0.5	in lake	9	W. F. Condit
INHS 6284	" "	" "	Nov. 11, 1931	0.6	6.	around island	28	M. L. Pontius
INHS 6344	" "	" "	Nov. 12, 1931	0.6	77.	upstream	189	Gus Butsch
INHS 6347	" "	" "	Nov. 12, 1931	0.5	1.5	downstream	251	Don Hughes
INHS 6523	" "	" "	Nov. 13, 1931	0.4	1.	downstream	216	" "
INHS 6565	" "	" "	Nov. 16, 1931	0.4	1.	downstream	34	Rex Hollenback

Table IV cont.—Migration of Illinois Fishes

WHITE CRAPPIE

Tag Number	Stream	Location	Date	Wgt., Lbs.	Water Distance Miles	Migration Direction	No. Days Tagged	Caught, or Reported by
INHS 2104	Ohio River	Allard Lake	Apr. 3,1930	0.35	3.	in lake	43	Henry Morrow
INHS 2844	Fox River	McHenry	July 16,1930	0.3	none	---	1	I. N. H. S.
INHS 3562	" "	Mouth of Indian Cr.	Sept. 8,1930	0.5	2.	downstream	29	E.E.Armstrong
INHS 4686	Illinois R.	1 mile south of Havana	May 11, 1931	0.2	8.	upstream	17	John Lane
INHS 4942	" "	Meredosia Bay	July 17,1931	0.55	0.67	in lake	0.4	I. N. H. S.
INHS 5491	" "	" "	July 31,1931	0.4	0.06	in lake	0.4	" " " "
INHS 5492	" "	" "	July 31,1931	0.5	0.06	in lake	0.4	" " " "
INHS 5288	" "	" "	Aug. 7, 1931	0.3	0.5	in lake	5	" " " "
INHS 5697	" "	Big Lake Pumping Station	Nov. 4, 1931	0.5	2.	downstream	7	W. T. Boyd
INHS 5724	" "	" "	Nov. 4, 1931	0.35	1.	in lake	7	I. N. H. S.
INHS 5903	" "	North Lake	Nov. 5, 1931	0.4	16.	upstream	117	Tom Ganer
INHS 5907	" "	" "	Nov. 5, 1931	0.4	18.	upstream	117	" "
INHS 5964	" "	Big Lake Pumping Station	Nov. 6, 1931	0.35	1.5	in lake	7	I. N. H. S.
INHS 5967	" "	" "	Nov. 6, 1931	0.4	1.	in lake	.5	" " " "
INHS 5968	" "	" "	Nov. 6, 1931	0.25	1.5	in lake	11	" " " "
INHS 6703	Rock River	Above Gov't Dam, Sterling	Apr. 19,1932	0.6	3.5	upstream	28	Charles Hippert
INHS 6943	Mississippi River	Wing dam above New Boston	Aug. 17,1932	0.35	1.	downstream	1	I. N. H. S.

Table IV cont.—Migration of Illinois fishes

Tag Number	Stream	Location	Date	Wgt., Lbs.	Water Distance Miles	Migration Direction	No. Days Tagged	Caught, or Reported by
			WHITE BASS					
INHS 2827	Fox River	500 yds.above McHenry	July 16,1930	1.1	6.	upstream	23	F.J.Pechousek
			ROCK BASS					
INHS 2204	Fox River	Mouth of Nippersink Cr.	June 7, 1930	0.5	2.5	upstream	6	G. J. Vichman
INHS 2205	" "	" "	June 7, 1930	0.4	none	---	1	I. N. H. S.
INHS 2602	" "	Outlet of Pistakee L.	June 26,1930	0.4	1.	in lake	3	Bob Becker
			BLUEGILL					
INHS 2561	Fox River	Mouth of Nippersink Cr.	June 23,1930	0.6	8.	upstream	108	Otto Schunemann
INHS 6779	Illinois R.	Senachwine L. Undercliff	June 21,1932	0.4	0.5	in lake	4	Leon Thompson
			PUMPKINSEED					
INHS 1509	Kaskaskia R.	5 miles S.E. of Sullivan	Aug. 2, 1929	0.15	none	---	1	I. N. H. S.
			GREEN SUNFISH					
INHS 4741	Spoon River	3½ miles above mouth	May 28, 1931	0.3	0.06	upstream	2	I. N. H. S.

Table IV cont.—Migration of Illinois fishes

CARP

Tag Number	Stream	Location	Date	Wgt., Lbs.	Water Listance Miles	Migration Direction	No. Days Tagged	Caught, or Reported by
USBF 7333	Rock River	Fuller Farm below Rockford	Mar. 12,1926	4.37	none	---	7	I. N. H. S.
USBF 7337	" "	" "	Mar. 12,1926	4.94	0.25	upstream	3	" " " "
USBF 7337	" "	" "	Mar. 15,1926	4.94	22.	downstream	750	John Eberley
USBF 7304	" "	" "	Mar. 15,1926	5.0	none	---	1	I. N. H. S.
USBF 7306	" "	" "	Mar. 15,1926	4.25	0.25	upstream	1	" " " "
USBF 7313	" "	" "	Mar. 15,1926	5.5	0.25	upstream	1	" " " "
USBF 7314	" "	" "	Mar. 15,1926	2.37	0.25	upstream	1	" " " "
USBF 7315	" "	" "	Mar. 15,1926	3.43	none	---	1	" " " "
USBF 7319	" "	" "	Mar. 15,1926	2.75	none	---	1	" " " "
INHS 633	Kaskaskia R.	3 mile below Carlyle	Aug. 22,1929	2.3	0.5	upstream	264	E.L.Steinmann
INHS 160	" "	" "	Aug. 25,1929	1.8	20.	downstream	310	H. F. Hanke
INHS 133	Fox River	2½ mile above St. Charles	Aug. 21,1930	2.0	0.5	upstream	30	Louis Nikodem
INHS 279	" "	1½ mile above Aurora dam	Aug. 27,1930	4.35	1.	upstream	990	John Pasilis
INHS 517	" "	Mouth of Indian Creek	Sept. 5,1930	5.5	none	---	663	Scott McCosh
INHS 529	" "	" "	Sept. 7,1930	1.5	none	---	1	I. N. H. S.
INHS 6082	Sangamon R.	Near Buck'sFord ab. Monticello	Sept. 9,1930	1.4	3.	upstream	956	Wm.F. Lodge
INHS 6604	" "	" "	Sept. 9,1930	1.6	12.5	upstream	310	R. B. Head

Table IV cont.—Migration of Illinois fishes

CARP-continued

INHS 3693	Illinois R.	Upper Free Bridge, Peoria	Oct. 22,1930	2.6	3.5	downstream	112	Lixon Fisheries
INHS 3771	" "	" "	Oct. 23,1930	2.3	3.5	upstream	51	" "
INHS 4024	" "	" "	Oct. 27,1930	2.2	3.5	upstream	4	" "
INHS 4155	" "	Water Works Point, Peoria	Nov. 5, 1930	1.6	none	---	1	" "
INHS 4218	" "	" "	Nov. 5, 1930	1.9	none	---	1	" "
INHS 4371	" "	Willow Point, Peoria	Nov. 12,1930	2.2	7.5	downstream	91	" "
INHS 4431	" "	" " "	Nov. 12,1930	2.0	2.	downstream	2	" "
INHS 3900	" "	Upper Free Bridge, Peoria	Nov. 18,1930	2.1	3.	upstream	22	" "
INHS 5568	Spoon River	4 mi. above mouth	Oct. 21,1931	2.4	3.	downstream	349	Perry L.Barnes
INHS 433	Illinois R.	1½ mile below Grand Island	Nov. 18,1931	1.0	2.	downstream	32	Rex Hollenback
INHS 435	" "	" "	Nov. 18,1931	1.7	8.7	" and into lake	272	Wm.LeTissier
INHS 446	" "	" "	Nov. 18,1931	1.3	2.	downstream	18	Rex Hollenback
INHS 598	" "	" "	Nov. 18,1931	1.6	5.	downstream	12	W. T. Boyd
INHS 664	" "	" "	Nov. 20,1931	1.2	5.	downstream	59	W. T. Boyd
INHS 806	" "	Havana, Ill.	Jan. 21,1932	4.8	2.5	downstream	106	Havana fisherman
INHS 965	" "	Undercliff B. L.Senachwine	July 4, 1932	5.2	6.5	upstream	281	Milo B.Lock
INHS 7389	Mississippi R.	1½ mi. above Savanna	Aug. 24,1932	2.7	7.5	downstream	222	V. Schumaker
INHS 7404	" "	" "	Aug. 26,1932	2.1	1.5	upstream	202	" "
INHS 7430	" "	" "	Aug. 30,1932	2.7	2.5	downstream	203	" "
INHS 7460	" "	2 mi. below Clinton, Ia.	Sept.20,1932	1.2	2.	downstream	162	E.J.Peterson

Table IV cont.—Migration of Illinois fishes

Tag Number	Stream	Location	Date	Wgt., Lbs.	Water Distance Miles	Migration Direction	No. Days Tagged	Caught, or Reported by
			PICKEREL					
INHS 2297	Fox River	Pistakee Lake	June 19,1930	1.5	5.	in lake	360	F. H. Amos
INHS 2298	" "	" "	June 19,1930	0.8	1.	in lake	80	" " "
INHS 2863	" "	McHenry	July 16,1930	1.9	none	---	1	I. N. H. S.
INHS 2932	" "	"	July 22,1930	1.25	6.	upstream	1174	Clarence Yelk
INHS 932	" "	"	July 23,1930	2.2	0.75	downstream	1131	Robert Woldt
			YELLOW PERCH					
INHS 5832	Illinois R.	North shore of North L.	Nov. 4, 1931	0.65	1.5	---	115	Harold Butsch
			SHEEPSHEAD					
INHS 4754	Spoon R.	3½ miles above mouth	May 28, 1931	0.45	3.5	downstream	3	I. N. H. S.
INHS 7414	Miss. R.	1½ miles ab. Savanna	Aug. 29,1932	1.45	67.	downstream	?	Earl Thompson
			COMMON RELHORSE					
INHS 3433	Fox River	Mouth of Indian Cr.	Sept. 5,1930	0.9	.17	downstream	3	I. N. H. S.

Table IV cont.—Migration of Illinois fishes

Tag Number	Stream	Location	Date	Wgt., Lbs.	Water Distance Miles	Migration Direction	Time Tagged Days	Caught, or Reported by
			CHANNEL CAT					
INHS 33	Sangamon R.	2 mi. above Monticello	July 16,1929	4.	4.	downstream	31	Edw. Pearson
INHS 3473	Fox River	Mouth of Indian Cr.	Sept. 6,1930	1.	1.	downstream	620	John Dummett
			FLATHEAD CAT					
	Sangamon R.	1½ mi.above Monticello	July 13,1929		3.5	downstream	36	Edw. Pearson
INHS 11	" "	"	July 13,1929	7.3	28	downstream	1067	Elmer O. Good
	" "	"	July 13,1929		8.	upstream	322	Fred Cox
INHS 7	" "	"	July 13,1929	12.1	30.	downstream	332	Elmer O. Good
INHS 24	" "	2 mi. above Monticello	July 15,1929	8.2	16.	downstream	745	" " "
			SPECKLED BULLHEAD					
INHS 2656	Fox River	Head of Grass Lake	July 2, 1930	0.4	none	---	1	I. N. H. S.
INHS 2658	" "	" "	July 2, 1930	0.4	none	---	1	I. N. H. S.

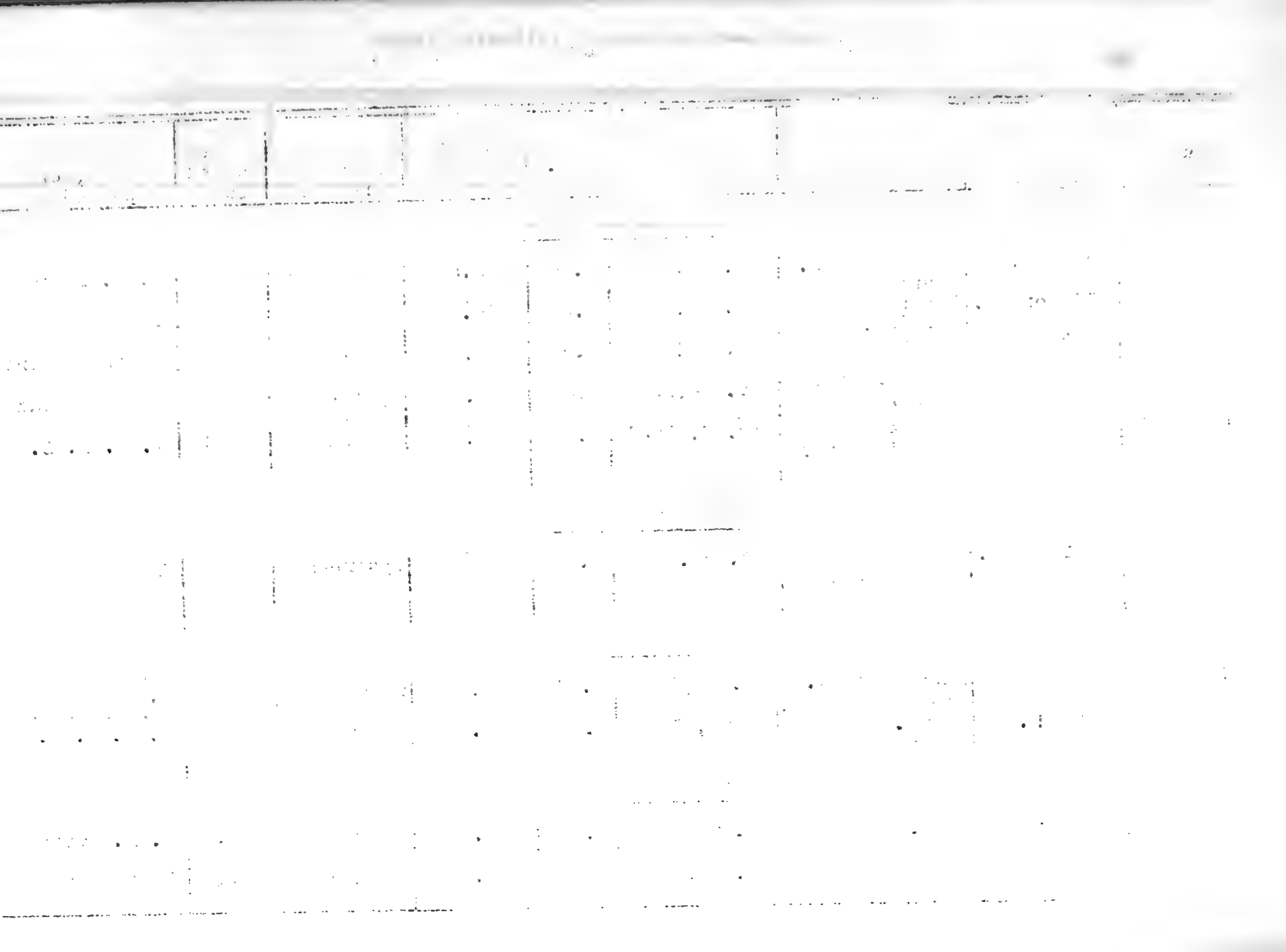
Table IV cont.—Migration of Illinois fishes

BLACK BULLHEAD

Tag Number	Stream	Location	Date	Wgt., Lbs.	Water Distance Miles	Migration Direction	Time Tagged Days	Caught, or Reported by
INHS 1093	Sangamon R.	2 mi. above Monticello	July 13,1929	0.3	none	---	1	I. N. H. S.
INHS 1174	" "	Above Springfield dam	July 25,1929	0.2	0.25	upstream	2	" " " "
INHS 1340	" "	Decatur Disposal Plant	Aug. 18,1929	0.2	0.01	downstream	1	" " " "
INHS 1359	" "	" "	Aug. 18,1929	0.25	0.01	downstream	1	" " " "
INHS 2313	Kaskaskia R.	2 mi. above mouth	Feb. 26,1930	0.5	15.	upstream	18	A.J.Nabelrath
INHS 2324	" "	" "	Feb. 26,1930	0.5	15.	upstream	18	" " "
INHS 2336	" "	" "	Feb. 26,1930	0.4	none	---	1	I. N. H. S.
INHS 2406	" "	" "	Feb. 27,1930	0.25	none	---	1	" " " "
INHS 2408	" "	" "	Feb. 27,1930	0.2	none	---	1	" " " "
INHS 2411	" "	" "	Feb. 27,1930	0.25	15.	upstream	17	A.J.Nabelrath
INHS 2464	" "	" "	Feb. 28,1930	0.45	none	---	1	I. N. H. S.
INHS 2470	" "	" "	Feb. 28,1930	0.35	28.	upstream	63	C. H. Kruse
INHS 2473	" "	" "	Feb. 28,1930	0.3	none	---	1	I. N. H. S.
INHS 2485	" "	" "	Mar. 1, 1930	0.3	2.	upstream	2	" " " "
INHS 5238	Illinois R.	Meredosia Bay	Aug. 5, 1931	0.8	5.	in lake	277	Theo. C. Coe

Table IV concl.—Migration of Illinois fishes

Tag Number	Stream	Location	Date	Wgt., Lbs.	Water Distance Miles	Migration Direction	Time Tagged Days	Caught, or Reported by
			RED MOUTH BUFFALO					
USBF 7258	Rock River	Winnebago Co. Farm	Feb. 26,1926	2.06	2.5	downstream	37	W. H. Denton
INHS 356	Illinois R.	Upper Free Bridge,Peoria	Oct. 21,1930	2.5	46.	downstream	170	Dixon Fisheries
INHS 4336	" "	" "	Nov. 11,1930	2.8	3.5	upstream	138	Dixon Fisheries
INHS 4505	" "	Andy Gowan's Point	Nov. 14,1930	2.3	10.	upstream	86	William Todd
INHS 6264	" "	Big Lake Pumping Sta.	Nov. 6, 1931	0.5	0.5	in lake	4	I. N. H. S.
			SMALL MOUTH BUFFALO					
INHS 360	Illinois R.	Upper Free Bridge,Peoria	Oct. 21,1930	2.5	3.	upstream	8	Lixon Fisheries
			QUILLBACK					
USBF 7254	Rock River	Winnebago Co. Farm	Feb. 26,1926	1.87	2.5	downstream	24	W. H. Denton
INHS 4746	Spoon R.	3½ mi. above mouth	May 28, 1931	1.0	0.5	upstream	2	I. N. H. S.
			BLACK SUCKER					
INHS 3282	Fox River	1 mi. above Aurora Dam	Aug. 27,1930	1.0	3.5	downstream	159	J. A. Sayer
INHS 3283	" "	" "	Aug. 27,1930	1.05	3.5	downstream	159	" " "



The carp, Cyprinus carpio L., furnished the largest series of returns. In Table V, p. 18, the 37 carp returns are divided into five convenient time periods and the migration constant is calculated for each. In contrast with the similarity of these calculated migration constants, the average distance per day varies widely, as may be seen in the last column.

Since the number of returns on other single species of fish is insufficient for statistical uses, I have lumped the data from all of the basses, crappies, and sunfishes—the so-called "fine fish." It may be seen in Table I that all of these have similar calculated rates of migration. These data have been arranged in three different time periods in Table VI, p. 19, where it may be seen that the calculated migration constants are more uniform than the average distances per day.

To determine whether fishes of different sizes migrate at different rates, the 37 returns from carp, which ranged from 1 to 5½ pounds, have been divided, in Table VII, p. 20, into four weight classes. The migration constants for these four weight classes vary from 0.23 to 0.66 but it is not considered that these numbers indicate any real differences in rate of movement between carp of different sizes.

In Table VIII, p. 20, these 37 carp have been divided according to streams, and migration constants calculated. The data on some of these streams are too fragmentary to be of much significance, but the returns from Fox River carp are sufficiently complete, and diverge from those of other streams so widely, that it seems certain that carp do migrate shorter distances there than in other streams. The reason for this lack of extensive migration in the Fox River is obvious since it is crossed at many points between McHenry and the mouth by dams. These dams are high enough to prevent fish going upstream at any time except during very high floods, and from going downstream, unless they go through the turbines or over the tops of the dams at flood stage. Furthermore the river was so low throughout 1930 and the years succeeding that carp are for the most part restricted to the pools immediately above these dams.

For 15 years the carp of the upper and middle Illinois River have exhibited an unusual abnormality referred to by local fishermen as "knothead" carp. We have learned that the knothead abnormality is caused during the early life of the carp by certain pollutional conditions which existed in the Illinois River. In the winter of 1926-27 when a detailed study of the knothead abnormality was made in the Illinois River, it was found that approximately 90 per cent of the carp from Peoria Lake and points upstream showed abnormality in greater or smaller degrees.

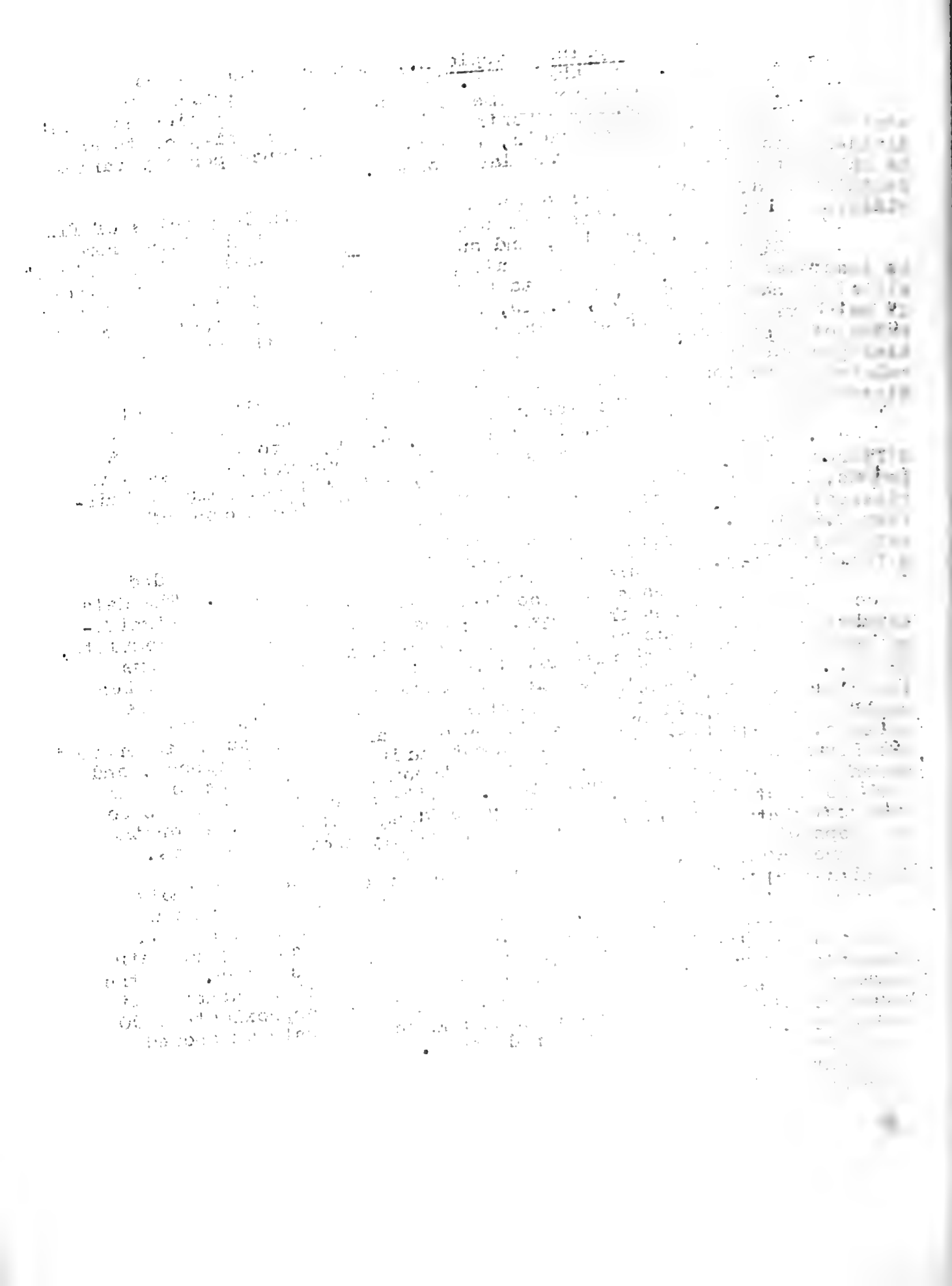


Table V.—Migration rate of carp, bearing tags varying lengths of time*

	Number of tags returned	Total number of days	Total number of miles	Rate of migration in miles per day	
				Calculated as water distance in miles divided by the square root of the number of days, and weighted by the number of days the tags were carried.	Average distance in miles per day.
Tagged 1-10 days	13	25	6.5	0.44	0.26
" 10-50 days	5	114	12.5	0.47	0.11
" 50-200 days	6	581	24.0	0.38	0.04
" 200-400 days	9	2413	62.7	0.44	0.03
" 400 or more	2	1706	25.0	0.41**	0.01
Total	35	4839	130.7	Carp migration constant 0.42	

*Since this paper was written, Dr. A. H. Hersh has brought to my attention D'Arcy Thompson's account (Growth and Form, p. 47) of the simulation of Brownian movement by the activities of living things (....Following with a pencil the track of each little swimmer and dotting its place every few seconds (to the beat of a metronome), Karl Przibram found that the mean successive distances from a common base-line, obeyed with great exactitude the 'Einstein formula,' that is to say the particular form of the 'law of chance' which is applicable to the case of the Brownian movement..."

**This figure does not include two carp from the Fox River which bore tags for 990 and 663 days, respectively. Due to numerous dams, and to prevailing low stages of water since 1930, the movements of these two carp were restricted to the pools above the Dayton and Aurora dams in which they were tagged. When they are included this figure is reduced to 0.22.

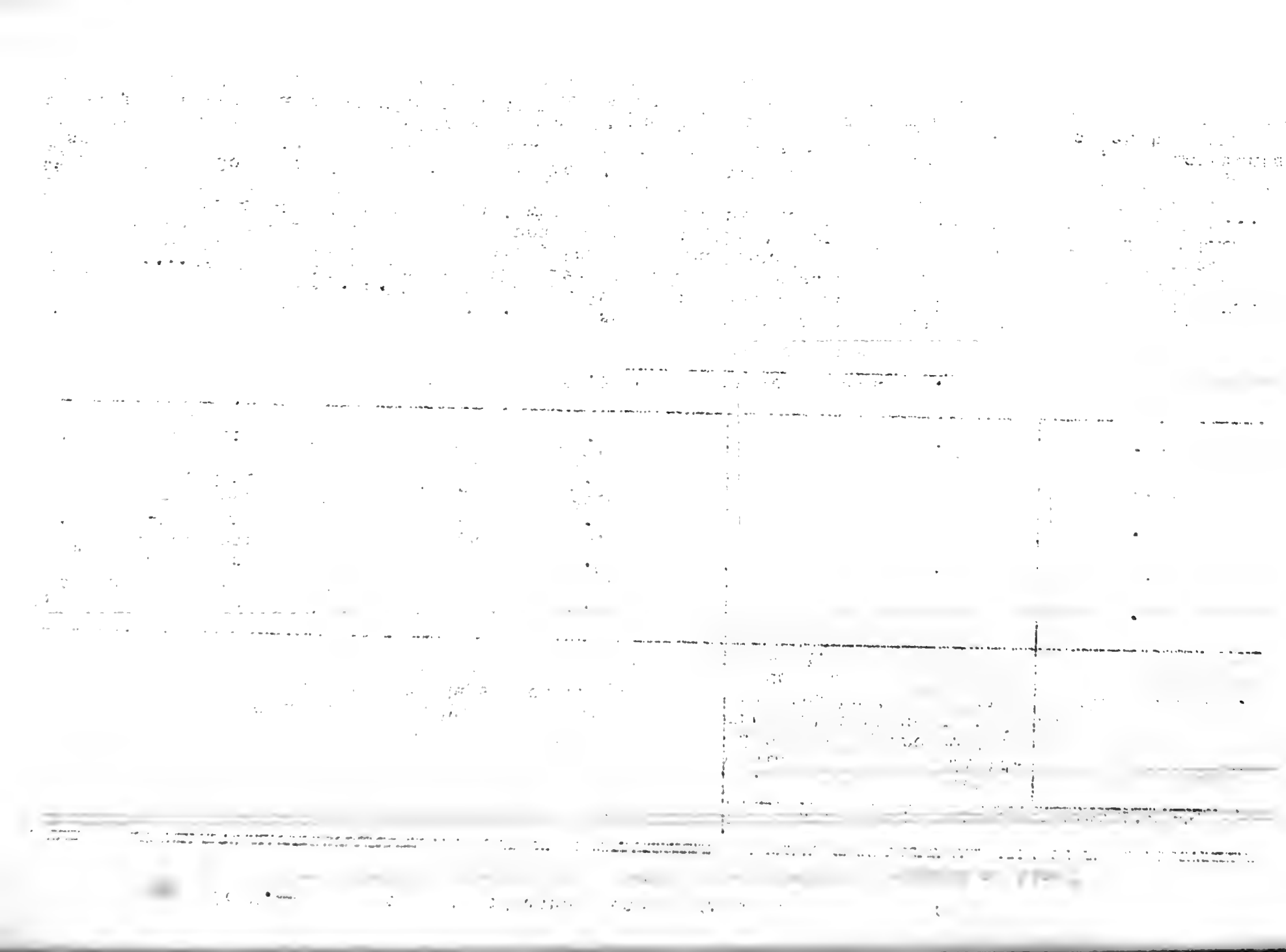


Table VI.—Migration rate of "fine fish,"—basses, sunfishes, and crappies, bearing tags over various periods of time.

	Number of tags returned	Total number of days	Total number of miles	Rate of migration in miles per day	
				Calculated as water distance in miles divided by the square root of the number of days and weighted by the number of days the tags were carried.	Calculated as average distance in miles per day.
Tagged 1-20 days	25	116.3	26.5	1.02*	0.33*
" 20-150 days	11	674	77.5	1.05	0.11
" 150 or more	4	878	88.5	1.41	0.10
Total	40	1668.3	192.5	"Fine fish" migration constant	1.24

*These figures are increased to 1.56 and 0.46 respectively when the 18 returns by I. N. H. S. are excluded. Since much of our fishing was done in restricted areas, these returns, while not covering more than a few days, do not give a fair measure of the migrations of such relatively fast moving fishes.

Table VII.—Migration rate of carp of different weights

Weight in pounds	Number of tags returned	Total number of days	Total number of miles	Calculated rate of migration in miles per day
1.00 - 1.65	9	1551	31.5	0.27
1.65 - 2.25	9	934	46.7	0.66
2.25 - 4.00	9	1204	20.75	0.23
4.00 - 5.50	8	1150	31.75	0.64*

*This figure is decreased to 0.27 when the two carp from the Fox River are included which bore tags 990 and 663 days.

Table VIII.—Migration rate of carp in different Illinois streams

River	Number of tags returned	Total number of days	Total number of miles	Calculated rate of migration in miles per day
Mississippi	4	789	13.5	0.25
Illinois	15	1064	54.7	0.48
Rock	9	766	23.0	0.79
Kaskaskia	2	574	20.5	0.63
Sangamon	2	1266	15.5	0.25
Fox	4	1684	1.5	0.02
Spoon	1	349	3.0	0.16

Carp from Havana and points downstream showed no abnormality, except for a few individuals, perhaps one in a hundred, which supposedly had straggled downstream from Peoria Lake. At points between Peoria and Havana, intermediate percentages of "knothead" carp were found. At Pekin, for example, about 30 per cent of the knothead abnormality occurred. These percentages were based on carp averaging about 5 years of age, hence it seemed clear that carp did not migrate any considerable distances in the five years from the time the knothead characteristic was determined in the fry stage until they were caught 5 years later, else the dividing line between knothead and normal carp would not be so clear-cut as it is between Peoria and Havana. Table I shows that the calculated average migration of a carp in five years is 17.9 miles. This figure was rather accurately predicted from a consideration of the distribution of knothead and normal carp in the Illinois River.

The data on tagged carp have been arranged in Table IX, p. 22, to show the rates of upstream and downstream migration. The rate of upstream migration shows a calculated migration constant of 0.24 miles in one day, while the downstream rate is 0.57 miles per day. I regard these rates as significantly different. The greater downstream rate may be a reflection of the effects of drouth since fishes commonly seek an optimal stream size and move downstream in times of drouth. The data on tagged "fine fish" show upstream movements almost ten times as rapid as downstream. The reason for this difference from the behavior of carp is not clear. It may be supposed that "fine fish," most of which are found in bottomland lakes and other quiet waters, travel upstream willy-nilly when they find themselves in a current. Their rate of migration in lakes is only one-fourth their upstream rate. It must be remembered that any fish which shows a preferential downstream movement under all conditions cannot long remain an Illinois fish and leave descendants to inhabit Illinois waters. Since these "fine fish" are not typical stream fishes, their reactions may be imperfectly adapted to stream life. This view seems to be supported by the low rates of migration found for typical stream fishes such as channel cat, common redhorse, black sucker, carp, and quillback. It appears that typical stream fishes are those which have a set of reactions which allow them to hold their place in a stream without crowding into the headwaters or being swept down to sea.

While the evidence obtained by analysis of statistics presented here shows that the movements of fishes are random in nature, it is not incompatible with many kinds of observations which show that the movements of fishes are directed, i.e., not random. These seemingly opposite views may be readily harmonized by supposing that this randomness of fish movement appears only as a gross relationship covering long periods of time, while those observations tending to show that fish movements are directed commonly apply to much shorter periods of time. A great number of physical variables in water affect the movements of fishes, and these are interrelated in so

Table IX.—The rates of upstream and downstream migrations of carp

Direction of migration	Number of tags returned	Total number of days	Total number of miles	Calculated rate of migration in miles per day
Upstream	13*	2126	35.5	0.24
Downstream	15	2700	95.2	0.57
Standstill	7**	13	--	--

* One carp which traveled upstream one mile in 990 days has been omitted because its movements were restricted to the pool above the Aurora dam.

** This excludes one carp which carried a tag 663 days and was retaken at the same place it was tagged in the pool above the Dayton dam on Fox River.

Table X.—The rates of upstream and downstream migrations of basses, sunfishes, and crappies,—so-called "fine fish"

Direction of migration	Number of tags returned	Total number of days	Total number of miles	Calculated rate of migration in miles per day
Upstream	11	736	163.06	2.41
Downstream	8	789	19.5	0.26
In lake	18	140.3	22.15	0.58
Standstill	3	3	---	--

complex a manner, and exist in such a constant state of flux, that no one factor is of sufficient importance or persists over a long enough period of time to produce marked variations from the appearance of randomness.

For example, it is well known that fishes move upstream in spring during times of heavy rainfall and floods. Conversely, they move downstream during summer and fall when streams are shrunken and suffer from drouth. This movement exists because most kinds of fishes prefer a stream of a certain size, some great and some small. When rains cause an increase in the volume of water, the fishes tend to move upstream until they find their optimal stream size. When drouth causes a shrinkage they tend to drift downstream until they find this same optimal stream size.

In winter, the Illinois River is occasionally covered with ice for periods of several weeks which halts the natural reaeration of the water and in the presence of pollution causes a deficiency of dissolved oxygen. Under such conditions fish are seldom killed unless they are caught in nets or are otherwise trapped and cannot escape suffocation. At such times they congregate in the mouths of tributary streams or crowd into "spring holes" which do not freeze. Observations at such times indicate that the fish do not blunder into the mouths of these tributaries and into "spring holes" but are guided to them by following slightly increasing amounts of dissolved oxygen from points downstream.

In the summer of 1931, while fishing in Meredosia Bay with fyke nets, near the mouth of a long narrow slough, we learned that on a certain night the dissolved oxygen in this water fell below the critical concentration and the fishes of this slough moved out into the bay in a body. We learned also that when fishes become embarrassed from lack of oxygen their movements are more rapid than at other times. Such a reaction tends to carry them over wider areas and will more probably bring them into higher concentrations of oxygen if such exist in the vicinity.

During autumn the fishes of certain of our swifter streams, such as Rock River, gradually accumulate in the eddies and quieter pools. By midwinter almost the entire fish population of the stream may be found in pools and eddies which make up only a few per cent of the total area of the stream. When the water warms in spring they leave these quiet spots and scatter until they may be found in about equal abundances in all velocities of water. This behavior, too, is essentially random in nature, since as the water cools the swimming movements of the fishes become so slow that they can no longer stem the current. Then they drift tail foremost downstream until they find water so quiet they can hold their position even though numbed by ice cold water.

Evidence that the movements of individual fishes are not completely independent of each other is furnished by certain fish tag returns. On February 26 and 27, 1930, Mr. Hunt tagged and released 99 black bullheads 2 miles above the mouth of the Kaskaskia River. On March 16, 1930 Mr. A. J. Nabelrath caught three of these tagged bullheads while fishing in Dooley Lake in the Kaskaskia bottomlands, 15 miles upstream. It is clear that these bullheads congregate into schools and travel together, since the possibility of three fishes being caught on the same day and at the same place after having traveled 15 miles by random movement is so remote that it may be regarded as outside the realm of experience.

If fishes moved in a strictly random manner it would be necessary for them to travel, during short periods of time, at velocities much higher than the observed velocities to make possible the daily rates given in Table I. For example, carp which are 0.42 mile distant after one day are calculated to move 7.5 feet in one second were their motions strictly random. In the same way "fine fish" with a daily migration of 1.24 miles are calculated to have a displacement of 22.3 feet in 1 second. The observed rates over such short periods of time are much slower than these calculated rates. A carp may swim at the rate of 7.5 feet per second during bursts of speed, but none of our fish can reach speeds of 22.3 feet per second. This divergence of the observed rates from the calculated rates is due to the fact that the movements of fishes are directed over short periods of time by environmental influences and due to the fact that a fish swims head foremost and is guided as if by a rudder. Direct observations of the movements of fishes show that they frequently spend considerable time in one place, or within a very circumscribed area, and then move rather directly to another place, several yards or more away. Here they may again hesitate and "mill around" for a time, and then proceed either leisurely or in a rather business-like manner in some other direction. The rate of these movements from place to place seldom exceeds more than 1 or 2 feet per second unless the fishes are frightened or are pursued.

Mimeographed Publications

of the Illinois State Natural History Survey

BIOLOGICAL NOTES

No. 1. The Migrations of Illinois Fishes. David H. Thompson. December 1933. 25 pp., 1 fig.

No. 2. Relative Growth in Polyodon. David H. Thompson. January 1934. 8 pp., 1 fig.

No. 3. The Automobile and Prairie Wild Life. W. P. Flint. July 1934. 7 pp.

No. 4. A Report on Tests of Fungicides for the Control of Elm Diseases in Nurseries. J. C. Carter. March 1935. 7 pp. With an introductory note by L. R. Tehon. 1 p.

No. 5. Suggestions for Management of Upland Game in Illinois. R. E. Yeatter. May 1935. 6 pp.